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MEASUREMENTS OF RADAR BACKSCATTER
FROM ARCTIC SEA ICE IN THE SUMMER

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by

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TABLE OF CONTENTS

ABSTRACT	ii
1.0 INTRODUCTION.	1
2.0 EXPERIMENT DESCRIPTION.	3
2.1 Experiment Location.	3
2.2 Sensor Description	5
2.3 Data Acquisition and Surface Truth	7
3.0 SUMMARY	12

LIST OF FIGURES

Fig. 1: The icebreaker "YMER" at anchor in the Arctic pack ice. . .	4
Fig. 2: The icebreaker "YMER" steaming through marginal ice zone first-year ice in its summer condition.	4
Fig. 3: Locations of radar sites in the Greenland Sea and Arctic Ocean	6
Fig. 4: Single 31 cm dish antenna shown mounted to the sling hook assembly of a Bell 206 helicopter.	8
Fig. 5: HELOSCAT II equipment package shown mounted in a Bell 206 helicopter.	8

LIST OF TABLES

Tab. 1: Nominal system specifications -- HELOSCAT II (YMER)	9
Tab. 2: Radar measurements and site information	10
Tab. 3: Description of sea ice types according to thickness and notations used to identify ice conditions described in Table 2.	11

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ABSTRACT

Measurements of radar backscatter from sea ice located near Svalbard and Greenland were made during the summer of 1980 as part of Project YMER. These data were acquired using the University of Kansas helicopter-borne microwave active spectrometer (HELOSCAT II) which operated over a frequency range of 8 to 18 GHz and an angle of incidence range of 0° to 50°. The presence of meltponds, the transformation of the snowpack into an ice layer, and the warmer temperatures have contributed to radar signatures that may be significantly different than those observed during the winter and spring. A wide variety of ice conditions were investigated. These included multi-year, thick first-year, thin first-year, young, new, and pressure-ridged ice. The measurement program is described herein.

7

1.0 INTRODUCTION

Robert G. Onstott was a participant during August 1980 in the Swedish Arctic Expedition, which was dedicated to the memory of A.E. Nordenskiöld's circumnavigation of Europe and Asia. Almost exactly 100 years later, the teams of scientists and engineers aboard the icebreaker YMER attempted to recreate the historic "Voyage of Vega" and sail the Northeast passage that was long sought by Nordenskiöld and his Swedish crew. On this voyage, which also extended to points no ship had ever been, a variety of scientific experiments were conducted. These included studies into the content of gases, aerosols, and particles in the Arctic atmosphere; the extent and pattern of water transport between the Arctic basin and the Norwegian Sea; the extent of the Pleistocene ice sheets in the European Arctic; the biological connection between the Arctic basin and the adjoining sea; the study of organic production and the amount of living organisms at different levels in the ecological system; the measurement of trace metals, hydrocarbons, and halogenated hydrocarbons in order to get a base line for the state of pollution in the Arctic Sea; the study of the dynamics of the eddy located at the ice edge near Fram Straits; the study of polar bears and birds; and the study of the radar backscatter properties of Arctic sea ice under summer conditions. This last experiment was the RSL/ONR program.

Approximately 100 engineers, scientists and technicians were engaged in the field work, either on board or on Arctic islands -- 35 of these were from the USA, Norway, Denmark, Finland, England, West Germany, France and Canada. There were 45 scientific institutions contributing to the research programs. Also aboard was an admiral, a commander, a chief, a Swedish crew of 50, a newspaper correspondent, a noted Scandinavian author who was writing

the story of the voyage, a painter who captured the beauty of the surroundings, and a film-maker who documented the research and the voyage on mylar.

The YMER icebreaker had a displacement of 8000 tons with 22,000 horsepower shaft output which was about four times the horsepower of ocean-going ships of this size. She carried two helicopters (Bell Jet Rangers), two ice tractors, four snowmobiles, two motor-powered rubber boats and a small hover craft. The ship cruised in open water at speeds of 15 knots and in 1.5 m ice at four knots.

Many categories of ice were encountered in their summer condition. Thicknesses of the ice that was studied ranged from 2 cm to greater than 6 m. Much of the ice was found to be in a rotten condition. Throughout the ice surface melt water had collected in pools. These were found to be many centimeters in depth and in the case of the ice less than 2 m thick, these pools opened into the sea water below. This and the fact that they were in areas which have the highest concentration of polar bears in the world meant that these floes were studied with "sincere caution."

It was apparent that there were many subcategories of ice that were encountered on the voyage. Varieties of visually different thick first-year ice were observed. This was also true of multiyear ice. The physical color of thick first-year ice ranged from greys to greens to medium blues and colors of multiyear ice ranged from medium blues to very bright blues with an occasional cream-colored green. An inspection of the salinity profiles will be made to detect differences in salinity. The regions in which the ice was observed and their salinity distribution may allow speculation about the origin of the ice. Also, what appeared to be a thin snow layer on the ice had transformed into a solid layer of large ice crystals (pop-corn ice) and had become an adherence to the ice sheet.

2.0 EXPERIMENT DESCRIPTION

Our role in the YMER mission was to acquire backscatter data from sea ice under summer conditions using a calibrated radar. These data will later be used in the qualitative and quantitative study of how the many categories of ice, influenced by the season, backscatter the energy of radar. This information is used to understand the interaction process and to describe the optimum radar parameters of operational radars used in producing large area-extensive photographic-quality maps of the Arctic and sub-Arctic regions. The HELOSCAT radar was mounted on YMER-ZULU, one of the ship's helicopters. This was a well-outfitted helicopter. It operated with gyro navigation gear, a radar altimeter, a Decca marine radar, an emergency tracking system, and the KU HELOSCAT.

The icebreaker provided a floating platform from which the backscatter missions were flown (Figure 1). The ship was located within the marginal ice zone (Figure 2) or in pack ice during the times of these investigations. This was an excellent logistics arrangement because transit time to-and-from ice floes of interest were virtually eliminated. Very often the floe at which the ship was anchored was the subject of the investigation. This enhanced both the acquisition of radar data and the performance of the surface truthing tasks.

2.1 Experiment Location

Measurements were made in the deep ocean north and northeast of Spitsbergen; the sea between Spitsbergen and Greenland; and the water off the northern coast of Greenland. Data were acquired as far west as the 27th meridian, as far east as the 15th meridian, as far north as the 83rd parallel, and as far south as the 77th parallel. The areas investigated with radar

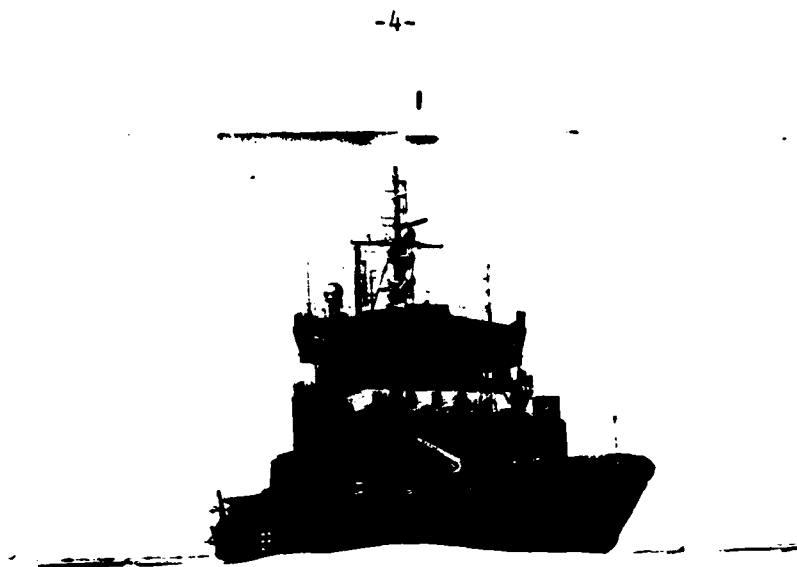


Figure 1: The icebreaker "YMER" at anchor in the Arctic pack ice.



Figure 2: The icebreaker "YMER" steaming through marginal ice zone first-year ice in its summer condition.

are indicated on the map shown in Figure 3. Note that the 80th parallel is located 600 nautical miles from the North Pole.

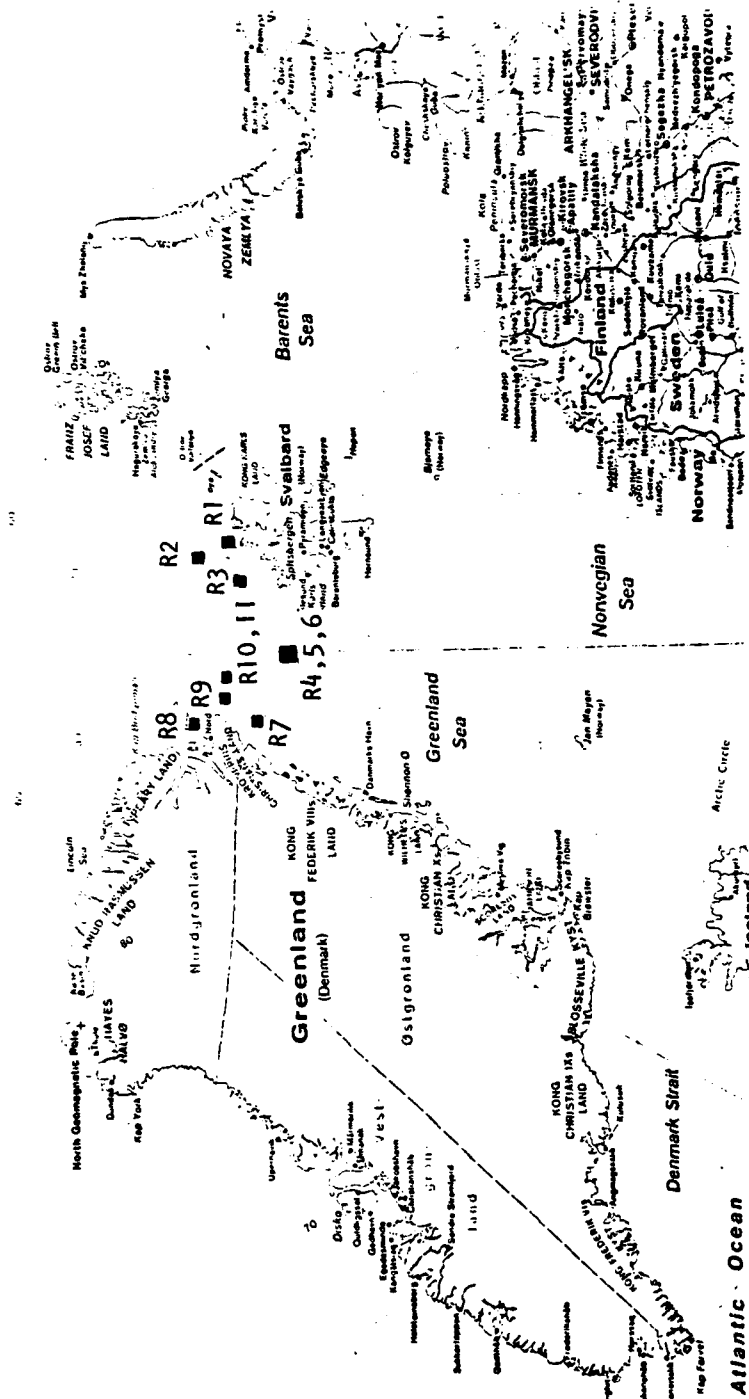
2.2 Sensor Description

The instrument used in the radar backscatter study was a frequency-modulated and continuous-wave calibrated radar operating in a single-antenna configuration. This radar scatterometer called HELOSCAT II differs in many aspects from the earlier helicopter-borne scatterometer, HELOSCAT I. HELOSCAT I was used in the 1978 and 1979 investigations. The second generation radar is capable of operating in both single- and dual-antenna configurations. Use of a single antenna relieves the need to electrically focus two antennas. There is, however, an acceptable tradeoff in system sensitivity. The radar data acquisition system was equipped with a microprocessor controller which multiplexed data onto analog cassette tape, whereas in the past, data was multiplexed onto thermal paper. It was also equipped with circuitry which automatically locates the centroid of the return spectra to the center of the IF signal-processing filters. This insures uniformity of measurement. In the past, data were acquired when a specified altitude was maintained. Deviation from this altitude required the discontinuing of data acquisition. The HELOSCAT II antenna platform was designed and fabricated to attach to any Bell 206B with high skids with or without emergency pop-out floats. This platform allows control of incidence angle changes from within the aircraft. In the past, angle changes were performed manually. Two antennas may be mounted to this platform. This allows like- and cross-polarization measurements to be made. This antenna airframe, however, was not used during the YMER experiment. The ship's helicopters lacked two clusters of hardpoints which are necessary for the attachment of this antenna structure. A small airframe was fabricated in the ship's workshop so that a 12" parabolic dish

FIGURE 3
Locations of Radar Sites in the Greenland Sea and Arctic Ocean

Arctic Ocean

North Pole



antenna could be installed under the belly of the aircraft. This structure utilized the sling hook assembly (Figure 4). Space constraints allowed only the small antenna to be fitted to the aircraft, thus limiting the operation of the radar to HH and VV antenna transmit-receive polarizations. The selectable angles of incidence were 0° , 13° , 25° , 38° and 50° . A complete listing of system specifications is given in Table 1. The equipment package is shown mounted in the helicopter in Figure 5.

2.3 Data Acquisition and Surface Truth

During many of the investigations of ice with radar the YMER icebreaker was at anchor at the area under study. The surface truth team of Peter Wadhams and Vernon Squire of the Scott Polar Research Institute and Robert Onstott of the University of Kansas were placed onto the ice with the ship's sky lift. Measurements were made of the physical and electrical properties of the ice. Upon completion of these tasks the surface party was evacuated and the backscatter measurements using the helicopter-borne instrument were made. This procedure allowed the surface measurements to be made prior to the ship's departure to a new location and in turn reduced the number of helicopter hours needed for the logistics effort of the surface party.

Many categories of ice were investigated. These included multiple types of thin, thick, and old pack ice and a small, shelf-iceberg. The dates of study, location, temperature, type, and the radar parameters are listed in Table 2. Table 3 describes the ice types according to thickness and the notation used to identify the ice conditions described in Table 2. Surface truth data were collected at selected locations. These data included (a) thickness, (b) temperature profile, (c) salinity profile, (d) horizontal and vertical inhomogeneities, (f) surface roughness and (g) strain in the



Figure 4: Single 31 cm dish antenna shown mounted to the sling hook assembly of a Bell 206 helicopter.

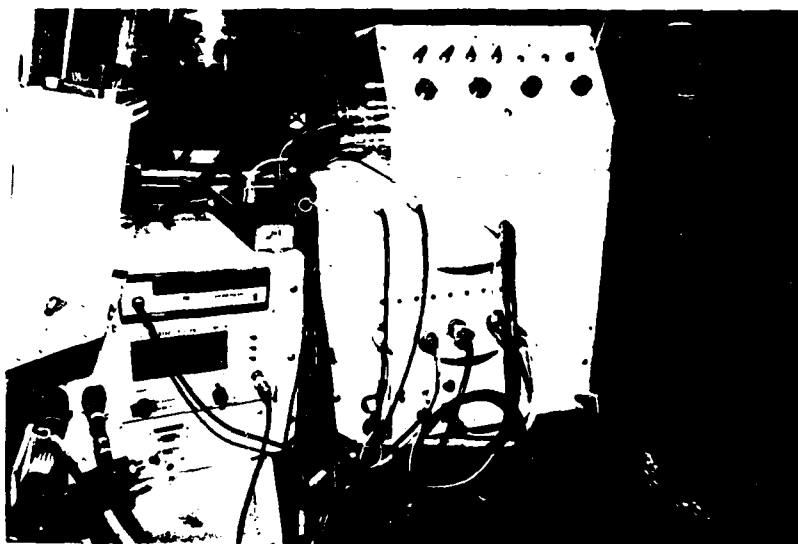


Figure 5: HELOSCAT II equipment package shown mounted in a Bell 206 helicopter.

TABLE 1
NOMINAL SYSTEM SPECIFICATIONS -- HELOSCAT II (YMER)

	<u>Ku-X-Band</u>
Type	FM-CW
Frequency Range	8-18 GHz
Modulating Waveform	Triangular
FM Sweep: Δf	1.0 GHz
Transmitter Power	14-19 dBm
Intermediate Frequency	50 kHz
Antenna:	
Size	31 cm reflector
Feed	Dual Ridge Horn
Polarization Capability:	VV and HH
Vertical Beamwidth	8.2° at 8 GHz 4.0° at 17.7 GHz
Horizontal Beamwidth	7.1° at 8 GHz 4.2° at 17.8 GHz
Incidence Angles Available	0°, 13°, 25°, 38° and 50°
Calibration:	
Internal	Signal injection (delay line)
External	Luneberg lens reflector
Helicopter Altitude	15 m

TABLE 2
RADAR MEASUREMENTS AND SITE INFORMATION

Site #	Date	Start	Flight Time -hr-	Latitude	Longitude	Temp °C Air Sea	Ice Type	Angle of Incidence Degrees From Nadir	RG-GHz	Antenna Polarization*
R1	8/14	1500	1	81° 34.4' N	22° 31.7' E	+6 -1.0	FY	0, 38, 25	9, 12, 17	VV
R2	8/15	1900	1	82° 19.19' N	22° 16.32' E	+1.9 -0.1	FY	0-50	9	VV
R3	8/19	1540	2	80° 59.81' N	14° 50.68' E	+1.4 -0.7	TFY, MY	13, 38	9, 10, 11, 12, 17	VV
R4	8/24	1832	1	79° 24.38' N	01° 52.35' E	-1.0 -0.5	Shelf	0, 25-50	9, 10, 11, 12, 17	VV
R5	8/25	1400	1-1/2	79° 30.95' N	00° 43.54' E	0.0 -1.0	New, MY	13-50	9-17	VV
R6	8/26	1500	2-1/2	79° 16.11' N	00° 19.78' W	-0.9 -1.0	TFY	0-50	9-17	VV
R7	8/28	1646	1-1/4	80° 13.80' N	12° 56.40' W	-1.5 +0.5	TFY, Rubble	13-50	9-17	VV
R8	8/30	1348	1-1/2	82° 23.67' N	16° 26.21' W	0.0 -0.6	MY	13-50	9, 10, 11, 12, 17	VV
R9	8/31	1201	2	81° 43.15' N	08° 47.14' W	-3.0 -0.5	TFY	0-50	9-17	HH
R10	9/03	0922	2-1/4	81° 40.60' N	03° 44.16' W	-4.9 -1.0	FY	13-50	9-17	HH
R11	9/03	1400	1-1/2	81° 39.40' N	03° 44.03' W	-4.7 0.0	PR	0-50	9-17	HH

TABLE 3
DESCRIPTION OF SEA ICE TYPES ACCORDING TO THICKNESS
AND NOTATIONS USED TO IDENTIFY ICE CONDITIONS
DESCRIBED IN TABLE 2

New	New Ice	0 - 5 cm
Thin	Thin Young Ice	5 - 18 cm
FY	First-Year Ice	30 - 90 cm
TFY	Thick First-Year Ice	90 - 180 cm
MY	Multiyear Ice	180+ cm
PR	Pressure-Ridged Ice	
MP	Meltpool	
SP	Snowpack	
Shelf	Shelf Ice	
Rubble	Zone of Strewn Block of Ice	

floes. The salinity profiles are included in Appendix B and the raw backscatter data (power returns) acquired by the HELOSCAT are included in Appendix A.

3.0 SUMMARY

Backscatter and physical-and-electrical properties data were acquired for the major categories of ice in the Greenland Sea area under late summer conditions. The power return data will be inverted into radar scattering cross-sections. The cross-sections will then be used in the description of angular and frequency responses. Variations of the radar cross-sections within floes will also be described. The physical properties data will allow the comparison of the physical change in the ice between spring and summer.

The compilation of data for this technical report may be found in RSL Technical Memorandum 331-22 as Appendix A: Raw Radar Backscatter Data and Appendix B: Sea Ice Salinity Profiles. This Technical Memorandum is available from the Remote Sensing Laboratory upon request.